Oceanographic Conditions in the Gulf of Maine for New Hampshire

Report submitted by the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS) to New Hampshire Department of Environmental Services, June 2013

Contents

Summary

Since the NERACOOS Gulf of Maine buoy array was initially deployed in 2001 the general trend has been for a warming of the region's coastal ocean waters. A comprehensive analysis of all the buoys with data up to 2011 showed that the warming trend was consistent at all buoys with the maximum rate of change noticed at intermediate depth in the deepest offshore buoys in Jordan Basin and the Northeast Channel (Morrison et al 2012). At the surface the rate of warming at the nearest buoy to New Hampshire, Buoy B, was 0.093 °C / year (± 0.038). Reanalysis of the time-series with data through May 2013 at the same location in this study indicated that the rate of warming for surface waters was 0.144 °C / year (± 0.037). Novel analysis of the rate of change of salinity at the same location indicated a general freshening of the surface waters (1 and 20 m) but no significant change in bottom waters (50 m). The warming trend observed at Buoy B might be part of cyclical changes in water temperature or part of a larger climatic shift.

Methods and Results

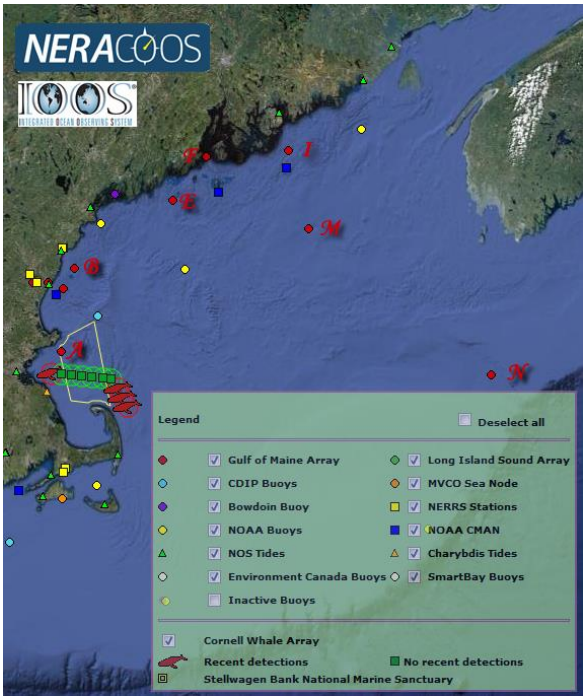

Figure 1.
Gulf of Maine observing system assets in the NERACOOS region with the Gulf of Maine buoys identified by their letters.

The Gulf of Maine buoy array of the Northeastern Regional Association of Coastal Ocean Observing Systems (NERACOOS, Figure 1) has been providing continuous oceanographic measurements for over a decade. NERACOOS is one of the eleven regional associations of the US Integrated Ocean Observing System (IOOS). The buoys are deployed and maintained by the Physical Oceanography Group of the University of Maine, initially as part of the Gulf of Maine Ocean Observing System. Currently there are seven buoys in the array sited at coastal shelf depths ranging from 50 to 250 m and providing temperature measurements at 3-7 depths throughout the water column.

In 2012 NERACOOS developed a tool to explore variations in daily and monthly observations compared to the long-term average conditions over the full time-series[1]. The average conditions, or climatologies, were calculated for a number of observed parameters including temperature and salinity. The climatology tool revealed that in 2012, six months were recorded as the highest monthly average temperatures recorded to that date.

[1] See http://www.neracoos.org/datatools/climatologies

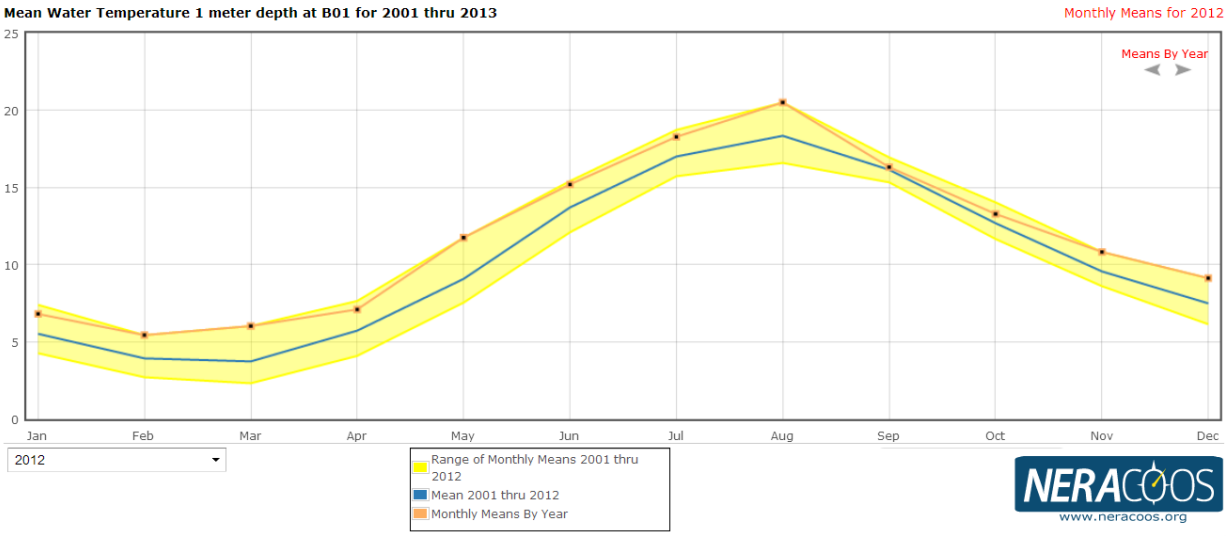

Figure 2.
Screenshot from the NERACOOS Climatology tool showing monthly water temperatures at 1 meter depth for Buoy B. The blue line is the mean value between 2001 and 2012, the yellow shaded area indicates the range of observations and the orange line and black markers the monthly averages for 2012. Monthly water temperatures for six of the twelve months of 2012 were the highest observed to that date.

The 2012 analysis of the large time series (over 10^5 samples for a single depth) showed statistically significant warming trends at all depths for all locations, providing the first depth-resolved rates of temperature variability for the U.S. East Coast from continuous data (Morrison et al 2012). Analysis steps included quality control of the data, calculation, and averaging of daily means and anomalies according to the decorrelation timescale (~ 20 days) and calculation of rates of change with linear regression. Use of the decorrelation timescale allowed for optimal determination of errors by assessing the number of unique samples within the large dataset, in which observations are closely correlated to adjacent records.

For this study which focused on the nearest buoy to New Hampshire (Buoy B), monthly averages were used with means calculated from approximately 30 days of observations, a similar timescale to that used for the previous study. Similar to the 2012 study, there were significant relationships between temperature variability and time ($p<0.05$), and all rates of change were positive and significant ($p<0.05$), although the temperature variability explained by time alone was again low (average 30%, Table 1). Although warming rates were not consistent with depth there were no significant differences between them as indicated by the overlap in the 95% confidence intervals (Figure 3).

The change of salinity was freshening at all depths but the rate was only significant at 1 and 20 m and not at the bottom. The amount of variability explained by time alone was low at the two depths where the rates were significant (both 6%) indicative of a weaker effect of time on salinity (Table 1 and Figure 3).

Table 1.
Rates of change and statistics for monthly mean properties at Buoy B.

	Rate of change (°C/yr or psu/yr)	Error	Min 95% confidence interval	Max 95% confidence interval	Number of monthly obs.	r^2	p
Water Temperature 1m	0.144	0.037	0.107	0.181	142	0.30	<<0.001
Water Temperature 20m	0.160	0.036	0.125	0.196	142	0.36	<<0.001
Water Temperature 50m	0.137	0.038	0.098	0.175	139	0.26	<<0.001
Salinity 1m	-0.044	0.030	-0.074	-0.014	122	0.06	0.005
Salinity 20m	-0.024	0.015	-0.039	-0.008	142	0.06	0.003
Salinity 50m	-0.009	0.012	-0.021	0.003	139	0.02	0.147

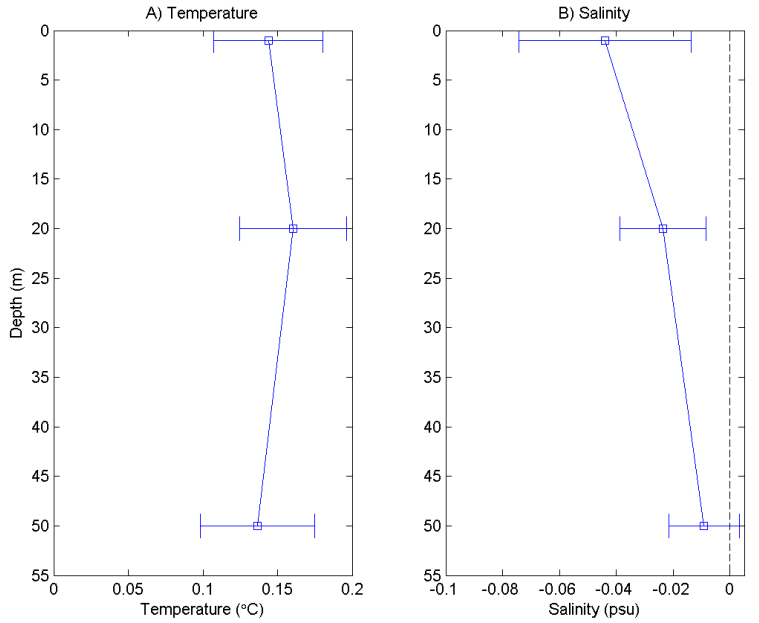

Figure 3.
The rate of change of temperature (A) and salinity (B) with depth at NERACOOS Buoy B. The error bars represent the 95% confidence interval. Rates of change and statistical coefficients are given in Table 1. At all depths water temperature showed a significant positive rate of change although there were no significant differences between the rates of change with depth. The negative rate of change of salinity was indicative of a freshening of the waters. Only the 1 m and 20 m rates were significantly different from zero.

Discussion

Both water temperature and salinity showed significant linear changes with time, the temporal signal in temperature being the stronger of the two. Water temperatures in 2012 were some of the highest on record with six of the twelve months being the greatest recorded to that date. The rates of change in water temperature derived from all data through May 2013 were of a similar scale as those in a previous study that used only observations up to 2011.

Long-term historical time series indicate that between 1940 and 1950 the Gulf of Maine warmed at approximately 0.25 °C yr^{-1}, followed by over a decade of cooling at a similar rate, all superimposed on an overall warming trend of 0.01 °C yr^{-1} (Shearman and Lentz 2010). The period of rapid warming recorded by NERACOOS Buoy B since 2001, of similar magnitude to the 1940-50 warming trend, may

represent another cycle of decadal variability or perhaps indicate a shift in the long-term warming trend.

References

Morrison J.R., Pettigrew N.R., O'Donnell J., and Runge J.A., 2012. Rapid detection of climate scale environmental variability in the Gulf of Maine. Oceans '12 Hampton Roads, MTS/IEEE.

Shearman and Lentz, 2010. Long-Term Sea Surface Temperature Variability along the U.S. East Coast. J. of Physical Oceanography. 40: 1004:1017

Other materials provided

Two Excel spreadsheets were provided as companions to this report. *Daily Data Downloads.xlsx* and *Monthly Data Downloads.xlsx* contained the data used in the NERACOOS Climatology Tool and this report including daily and monthly derived means for the whole time series and for each year between 2001 and May 2013. Worksheets within each spreadsheet were present for each depth for temperature and salinity. In addition figures similar to that in Figure 2 were provided for each year and each parameter.